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Demographic trends of a reintroduced Iberian ibex *Capra pyrenaica victoriae* population in central Spain

Abstract: One reintroduced population of Iberian ibex was monitored between 2000 and 2007 in the Sierra de Guadarrama National Park (Central Spain) using the distance sampling method. The densities obtained from three samplings show a significant increase between 2000 (6.57 ind./km^2) and 2007 (33.16 ind./km^2) despite a range extension. After an initial period of balance, the sex ratio became unbalanced over time in favor of females. The age pyramid also changed after a dramatic population increase. The birth rate oscillated at relatively high values for the species (0.69–0.99 kids/female). The group size reduced significantly over time. Females with kids dispersed from the release area significantly less than males and mixed groups.

Keywords: Bovidae; Caprinae; group size; population parameters; reintroduction.

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Introduction

The introduction or reintroduction of ungulates is closely linked to human activities and movements (Christie and Andrews 1966). While knowing the population parameters is fundamental to understanding the process of reintroduction of a species (Converse et al. 2013) and their relationship with the environment (Chapman 1928, Odum 1986), population monitoring has been carried out only in a few cases (Girard et al. 1998, Largo et al. 2008, Goldstein and Rominger 2011). Additionally, only some of these studies were performed in order to monitor the evolution of the most important population parameters during the reintroduction process. Therefore, the proposed models of demographic evolution are not always successful (Largo et al. 2008).

The Iberian ibex (*Capra pyrenaica* Schinz, 1838) is presently an endemic wild ungulate of the Iberian Peninsula that is distributed in the major mountain ranges of the eastern and southern of the Peninsula, as well as in Macizo de Gredos (Herrero and Pérez 2008) thanks to numerous colonizations and reintroductions during the second half of the twentieth century (Refoyo 2012).

The reintroduction of the Iberian ibex in Sierra de Guadarrama National Park began in 1990 with specimens of *Capra pyrenaica victoriae* Cabrera, 1911 subspecies from a preserve adjacent to the National Hunting Reserve of Gredos and Las Batuecas National Hunting Reserve. A total of 67 specimens (41 females and 26 males) were reintroduced by the time it was finalized in 1992. The average age of the population was around 5 years, and the sex ratio of the introduced specimens favored females at a proportion close to 1.6:1 (41 females and 26 males). However, among juveniles (under 5 years), the sex ratio favored males 1:1.4. On the contrary, there was a predominance of females in the individuals older than 5 years in a ratio close to 2:1. These ratios were in accordance with those used 63 for other ibex reintroductions (Girard et al. 1998).

The aim of this work was to establish the evolution of the population during the settlement and colonization of the reintroduced Iberian ibex. Our goals were: (1) to determine how the population has changed since its reintroduction; (2) to analyze the variation that has occurred in the most important population parameters during this period; and (3) to analyze the aggregability variation of the population during this process.

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Materials and methods

Study area

The monitoring studies were performed in an area of 4890 ha included within the Sierra de Guadarrama National Park (SGPN) (Figure 1) that shows a marked difference in altitude (between 2200 and 1100 m), alternating very steep rocky areas ("Las Pedrizas") with areas of gentle topography. The climate of the Sierra de Guadarrama is typically continental with large temperature variations between seasons and very dry summers. These temperatures may vary considerably depending on the altitude. The vegetation includes shrubs (*Cytisus purgans*, *Juniperus communis nana*) and grassland (*Festuca indigesta*, *Nardus stricta*, *Festuca rubra*) in highland areas; areas of Mediterranean shrub (*Cistus ladanifer*, *Rosmarinus officinalis*, *Thymus vulgaris*, *Lavandula stoechas*) in the steeply sloped areas, and forests (*Quercus ilex*, *Quercus pyrenaica*, *Pinus* spp.) in the valleys and hillsides.

Population monitoring

The reintroduced population was monitored between May 19th and June 12th during three campaigns in 2000, 2005, and 2007 (Refoyo 2012) by direct observation of the animals along transects using the distance sampling method (Buckland et al. 1993). For each contact, we recorded the habitat; the number, sex, and age of the individuals using 8×40–10×50 binoculars; and the perpendicular distance to the transect line using a laser distance meter (Bushnell Yardage Pro Sport). The same eight people walked along 22 transects per campaign, which had an average length of 3.64 km. There were slight differences between campaigns due to the inaccessibility of certain areas and due to the difficulty of retrieving each of the preset transects (Figure 1).

All of the transects were sampled on successive and climatically suitable days, either in the morning (2–3 h after sunrise) or afternoon (2–3 h before sunset).

Demographic parameters

The Distance 6.0 program was used to calculate the population density (Thomas et al. 2009). This software has been specifically designed for obtaining animal population densities by the linear transect method through observations from fixed points (Burnham et al. 1980).

These density data were related to the occupation area of the species in order to determine its rate of dispersion.

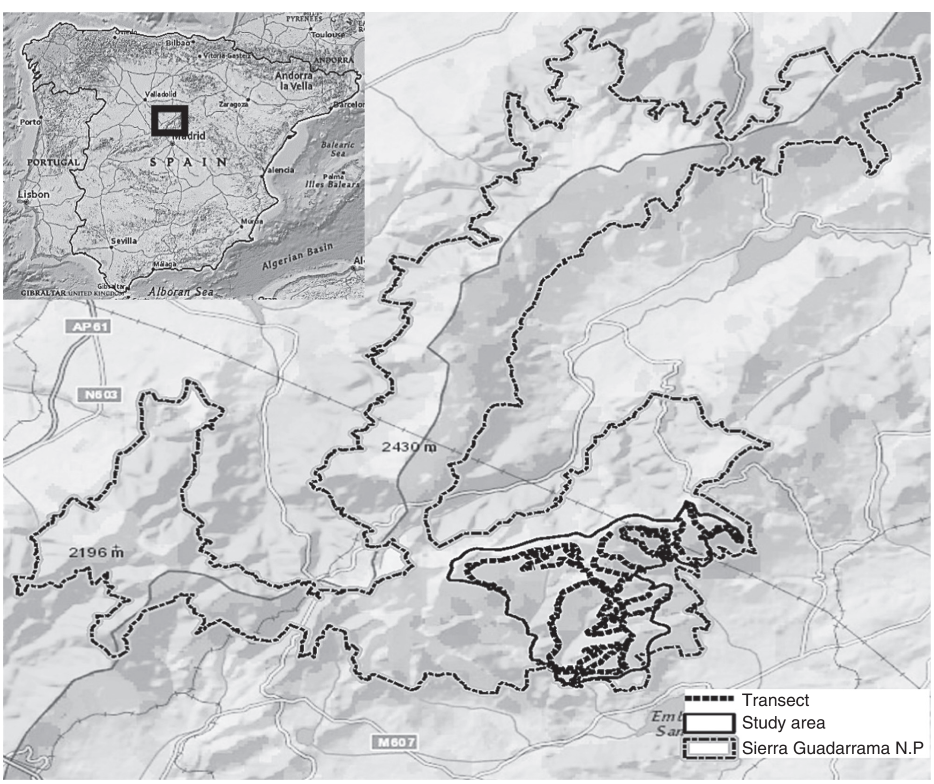

Figure 1 Location of the study area in Sierra de Guadarrama, itineraries performed and their location within the study area (22 transect walks per campaign with an average length of 3.64 km).

To set the dispersal area, we used the Minimum Convex Polygon (MCP), which marks the dispersion degree of contacts (Mohr 1947).

The population parameters that we studied were the sex ratio and the refined birth rates, for which the contacts were grouped according to age classes. In addition to the kids (individuals <1 year old), each sex was differentiated into two age classes in order to minimize the number of mistakes made during the observations and to include as many specimens as possible in the classification. The classes were juvenile female (1–3 years old); breeding female (over 4 years old), safer reproductive age (Giacometti and Ratti 1994); juvenile male (1–4 years old); and breeding male (more than 5 years old) (Fandos 1991).

The refined birth rate (RBR) has been expressed as the total number of kids born per total number of adult females (Fandos 1991).

The group types were also registered in spring and were categorized by sex and age: males alone, females alone, females with kids, and mixed groups.

Statistical analysis

Different statistical analyses (ANOVA) were performed using the General Regression Module of Statistica 7.0 (StatSoft Inc., Tulsa, OK, USA) and the Excel pivot tables (Microsoft Office Excel 2010). In order to identify the differences among years or group types, we have calculated *post hoc* tests after the ANOVAs. We selected the Fisher's least significant difference (LSD) test to compare the size of the group by campaign (only three campaigns) and Scheffé for the other two analysis (unbalanced groups).

Results

Density

The models (key function and series expansion) that were selected for the density estimations for the three analyses were the same (semi-normal cosine order 2), but not the statistical results (Table 1). Truncating distance and intervals number are also shown in Table 1.

The density obtained for each campaign shows a significant increase between 2000 when the estimated population was 356 individuals (6.57 ind./km^2), until 2007 when the population was 1523 goats (33.16 ind./km^2) (Table 1). Between the reintroduction and 2000, we noticed a population increase of 23%, followed by a 36% increase between 2000 and 2003. At last, the population has been increasing by 19% annually from 2003 to 2007.

This increase was associated with the population occupying a larger area, which increased by 56% in these years from 2101.67 ha in 2000 to 3278.87 ha in 2007, with an increase by 29% between 2000 and 2003 and 9% between 2003 and 2007.

Population parameters

Sex ratio

In 2000, 111 females and 95 males were detected, revealing that in the decade since the initial release until the first sampling, the sex ratio of the population had gone from 1.6:1 to 1.2:1 in favor of females and showing a tendency toward equilibrium in the population. Such a balance was maintained in 2003. However, in 2007, a new imbalance ratio (1.4:1) was detected in favor of females.

Age pyramid

The information that exists for the founding population core is the age of 48 of the 67 reintroduced specimens. Of these, 38 were breeding specimens, and 10 were juvenile individuals.

Until 2000, there was a significant increase in youngs, which represented almost 50% of the population. Since then, the percentage represented by the youngs decreased to 36% in 2007 (Table 2).

There were clear differences in the ages of males and females. Juveniles represented 60% of males in 2000, only 48% in 2007. The trend was similar for females, though the increase in the early years was lower (40% of youngs in 2000), before it decreased to 30% in 2007 (Table 2).

Birth rate

The refined birth rate 0.76 kids/adult female in 2007 rose to 0.99 kids/female in 2003 and reduced to 0.68 kids/adult female in 2007.

Grouping pattern

The specimens' aggregability gradually decreased during the spring time when the observations were made. The groups were increasingly disaggregating, and the average

Table 1 Evolution of the number of animals and density of Iberian ibex between 2000 and 2007 in Sierra de Guadarrama National Park.

Year	Number of animals	Density (ind./km²)	Coefficient of variation (CV%)	Truncating distance (m)	Interval numbers	f(0)	p-Value	Degrees of freedom	95% Confidence interval	
Founding core	67									
2000	359	6.67	38.47	350	3	0.0098	0.29	39	3.149	14.146
2003	773	16.83	25.50	300	3	0.0090	0.36	117	10.238	27.669
2007	1523	33.16	25.06	160	6	0.014	0.44	32	20.129	55.016

f(0) value of probability density function at zero for line transects=1/u (u=W*p); W, width of line transect; p, probability of observing an object in defined area. Truncating distance (m), maximum detection distance.

Table 2 Evolution of age and gender ratios of Iberian ibex in Sierra de Guadarrama National Park.

Gender	Age	Founding core[a]	2000	2003	2007
Male	Reproductive	71.42	39.52	47.22	51.75
	Juvenile	28.58	60.44	52.78	48.25
Female	Reproductive	85.19	59.46	70.37	70.95
	Juvenile	14.81	40.54	29.63	29.05
Total	Reproductive	79.17	50.50	59.48	63.17
	Juvenile	20.83	49.50	40.52	36.83

[a]Age of 48 of the 67 reintroduced specimens.

size was significantly reduced between 2000 and 2007 from 9.29 individuals to 4.73 (F 2191=3.529; p=0.031) (Figure 2). The groups consisting of females were smaller than the groups of females with kids, and the groups of males. The mixed groups were the largest. These differences were significant (F 3260=11.340; p<0.001) (Figure 3).

Considering the dispersion of the groups, both groups of males and mixed groups were located in areas furthest from the release point, while groups of females and females with kids tended to be located in areas closest to this point (F 3260=3.722; p=0.012) (Figure 4).

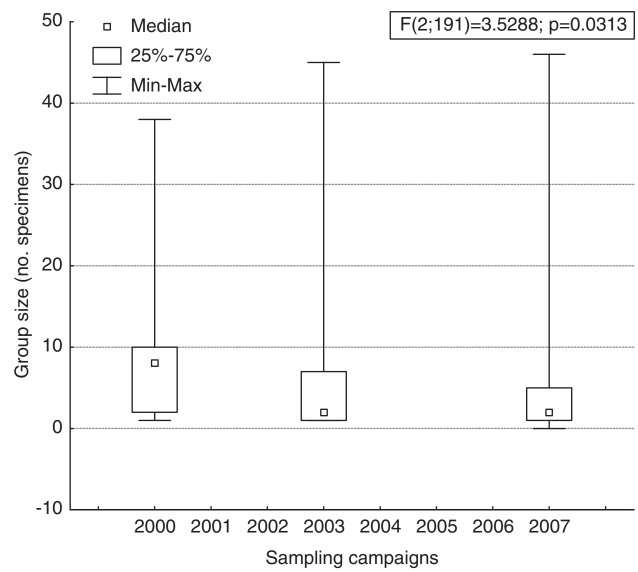

Figure 2 Numbers of individuals detected per group while the settlement in the territory progresses. The group size was significantly reduced by the process of colonization especially between the campaigns of 2000 and 2007 (*post hoc* LSD test: MS=70.12, df=191; p=0.009).

Discussion

The values obtained in this work exceeded the densities obtained for other populations of the genus *Capra* (Dupré et al. 2001, Martínez et al. 2002, Pérez et al. 2002, Sánchez-Hernández 2002, Carnevali et al. 2009, Fandos et al. 2010) (Table 3).

This population increase was high, possibly because it was reintroduced in a protected area without natural predators, with temperate climatic conditions (Toïgo et al. 1997, Scillitani 2011) and without domestic flooks. Moreover, the adequate proportion of females and males, and the ages of animals in the reintroduced group (Girard et al. 1998), are some of the reasons, which allowed for these increases. Therefore, the only limitations on the population are the carrying capacity of the area and the possible impact of diseases and parasitosis.

The sex ratio values obtained in our study are similar to those detected in other *Capra* populations by Ferreres et al. (2007) in Beceite, by Fandos et al. (2010) throughout Andalucía, and by Scillitani (2011) in Marmolada Massif (Italy). In all of these studies, there was an imbalance in favor of females in most populations.

The evolution of the sex ratio can be explained when it is analyzed in conjunction with the evolution of the age, which showed a significant increase in the youth population (especially males) in the early years and then stabilized close to one-third of the population. First, the population grew rapidly and promoted the presence of males; then, females were favored. This agrees with Senar (in Carranza 1994) who reported that in polygynous

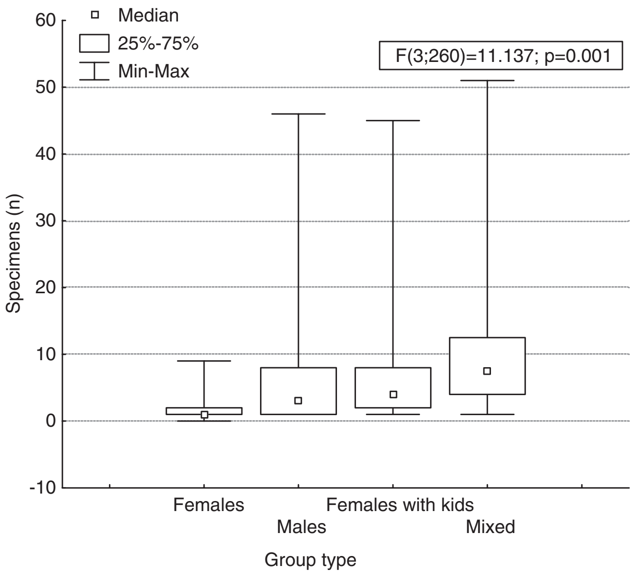

Figure 3 Relationship between group size and group type considering the different samples. Females form groups much smaller than males. Mixed groups and females with kids show average sizes [*post hoc* Scheffé test: MS=64.93, df=260; p=0.004 (female/male); p=0.002 (female/female with kids); p=0.000 (female/mixed)].

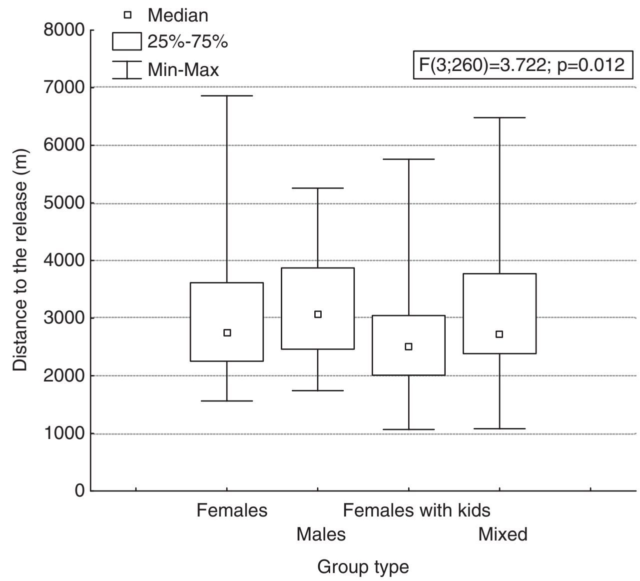

Figure 4 Relationship between group type and the releasing point. The female groups with kids have moved less away from the colonization point, while males have presented more dispersion [*post hoc* Scheffé test: MS=1210E3, df=260; p=0.039 (female with kids/males)].

populations, there is a larger production of males when the environmental conditions are favorable and a larger production of females when they worsen.

In our study, the refined birth rate was higher than in other populations despite the high densities even if this index progressively reduced with increasing density as it was already reported by Fandos (1991) in Sierra de Cazorla (0.55) and Pérez et al. (2002) in Sierra Nevada (0.3–0.7). However, our values exceeded what is common in colonizing populations, which may be related to a high survival of kids (without natural enemies and competing domestic flocks in the area) and a scattering of specimens outside the studied area. Duarte et al. (2007) determined that the species productivity tends to be 0.33 kids/female. Although the Beceite's population (Ferreres et al. 2007) and Marmolada's population (Italy) (Scillitani 2011) had very similar values to the ones obtained in our study, they were always lower than 0.7 kids/female.

The aggregability of the Iberian ibex in the study area evolved since its release, the group size having reduced over time. While the groups with more than 10 animals reached nearly 20% in 2000, this percentage dropped to 8%, when the groups with less than five animals increased from 45% to 78%. These values are close to those obtained

Table 3 Maximum densities in different populations of *Capra ibex* and *Capra pyrenaica*.

Species	Area	Density (ind./km^2)	References
Capra ibex	Croda Rossa (Bolzano-Belludo)	0.2	Carnevali et al. 2009
	Tarviso Colony (Udine)	15.73	Carnevali et al. 2009
	Stelvio National Park	10	Carnevali et al. 2009
	V. Lanzo-G. Paradiso-M. Bianco	10–15	Dupré et al. 2001
	Alpi Retiche-Ortles-Cevedale	3–10	Dupré et al. 2001
	V. Formazza-V. Grande	1–3	Dupré et al. 2001
Capra pyrenaica hispanica	Sierra Cazorla	11	Alados and Escos 1985
	Sierra Nevada	8.79	Fandos et al. 2010
	Sierra Madrona	2.9	Sanchez Hernandez 2002
	Tortosa-Beceite	15	Martinez et al. 2002
Capra pyrenaica victoriae	Sierra Gredos	15	Pérez et al. 2002
	Sierra de Guadarrama National Park (4.890 ha)	33.16	Refoyo 2012

in Andalucía (from 1.29 ind. in Cazorla to 8.25 ind. in Sierra de Loja, Fandos et al. 2010).

This pattern may reveal a defensive group behavior during the first years after the release (Senar in Carranza 1994), when the animals feel more secure in larger groups. After they settled, the groups tend to disintegrate.

We reported that males were more gregarious than females, which is common in the spring period (Refoyo 2012). This difference may be motivated by the larger mobility observed for males. By contrast, females were more localized in specific areas where they did not require large groups for self-protection. In Cazorla during the spring, Alados and Escos (1995) reported that male home range was 400 ha, when females only ranged over 25 ha. In Sierra de Guadarrama (Refoyo 2012), the difference was smaller with 741 ha for males and 308 ha for females.

Male groups are those with greater dispersion from the release point coinciding with other studies which establish that male ibexes select different habitats and move more than females (Alados and Escos 1995, Parrini et al. 2009). Furthermore, the releasing point coincides with a rocky area that is more preferred by females. Females are more dependent on steep terrain throughout the year than males (Parrini et al. 2009) and especially during the breeding season (Refoyo 2012).

Our results suggest that the population settled perfectly in the area of reintroduction. Nevertheless, the low dispersion of the specimens (<4 km from the location of release) results in an excessive concentration in very specific areas, which is negatively affecting the vegetation. Therefore, we recommend a plan for promoting the dispersion of the animals.

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